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PRESENT DEVELOPMENT IN THE FIELD OF PERMANENT MAGNETS[1]

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Expansion of the production and applications of permanent magnets. Primary magnetic properties and magnet performances. Magnetic anisotropy and coercive force of fine particles. Survey of basic hard magnetic materials. Magnetic properties of permanent magnets produced in Czechoslovakia and abroad. Increase of requirements from industry on the assortment and the properties of magnets. Recent results of research on hard magnetic materials. Perspective materials Mn—Al, R—Co and Fe—Cr—Co. Raw materials for permanent magnet production. Impact of increased cobalt prices. Problems of economical efficiency of rare earth cobalt magnets. New type of magnets with enhanced magnetic induction developed in SVÚM. Some new applications of magnets. Permanent magnets as means of electrical energy savings. Present objectives of fundamental and applied research on hard magnetic materials.

СОВРЕМЕННОЕ СОСТОЯНИЕ ИССЛЕДОВАНИЙ В ОБЛАСТИ ПОСТОЯННЫХ МАГНИТОВ

Развитие производства и применений постоянных магнитов. Первичные магнитные свойства и параметры магнитов. Магнитная анизотропия и коэрцитивная сила малых частиц. Обзор основных групп магнитнотвердых материалов. Магнитные свойства постоянных магнитов выпускаемых в Чехословакии и за рубежом. Рост требований промышленности на ассортимент и свойства магнитов. Новые достижения исследования магнитнотвердых материалов. Перспективные материалы Mn—Al, R—Co и Fe—Cr—Co. Сырё для производства магнитов. Влияние повышенных цен кобальта. Проблемы экономической эффективности магнитов на основе редкоземельных элементов. Новый сорт магнитов с повышенной магнитной индукцией разработанный в СВУМ. Некоторые новые применения магнитов. Постоянные магниты как средство экономии электрической энергии. Современные задачи основного и прикладного исследования.

The world's production of hard magnetic materials continues to increase and it is estimated almost to double every decade. The evaluation of the total production

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should be done not only in thousands of tons but rather in the light of several billions of pieces produced every year for use in an enormous quantity of devices.

The large majority of permanent magnets needed by the Czechoslovak industry comes from inland production. Various types of hard ferrites (trade name DUROX) and cast Al—Ni—Fe and Al—Ni—Fe—Co (trade name PERMAG) are commercially produced in large quantities, while Cu—Ni—Fe, Cu—Ni—Co—Fe, plastic bondes isotrope ferrites and magnet steels are used on a smaller scale. Sintered $SmCo_5$ and mischmetal—Co_5 magnets [1] are available only in very limited series from laboratory production. The magnetic properties are comparable with current values of magnets manufactured abroad.

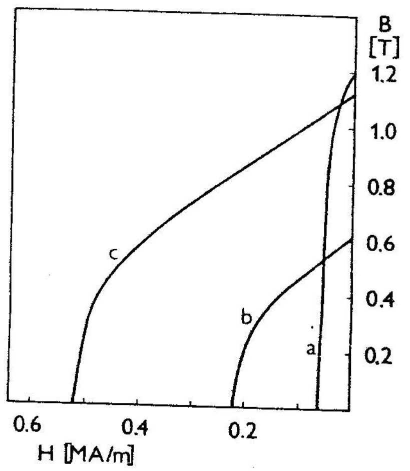

Fig. 1. Representative demagnetization curves taken from literature: (a) — Fe-33 % Cr-11.5 % Co, (b) — Mn-29.5 % Al-0.5 % C, (c) — Co-25.5 % Sm-8 % Cu-15 % Fe-1.5 % Zr.

In addition to the requirement of a maximum energy product at a reasonable price there are industial interests in an increasing resistance do demagnetization, an improving machinability, a minimizing temperature coefficient and extending operating temperature limits.

Recently, the interest of the research in the properties of Mn—Al—C, Fe—Cr—Co and $R_2(Co,M)_{17}$ systems has been growing (Fig. 1); the Mn—Al—C alloy which, being made from cheap and abundant raw materials, has the potential to provide new low-cost and high quality permanent magnets because of its higher saturation magnetization and more favourable temperature coefficients over ferrites [2]. Fe—Cr—Co alloys have magnetic properties which may compete with the Alnicos, yet they are machinable and somewhat less expensive [3]. In the field of rare earth cobalt magnets where the possibilities of improving have far not been exhausted, the main point of research has recently shifted to the $R_2(Co, M)_{17}$ systems and magnets with an energy product exceeding 240 kJ/m^3 were developed [4].

The present situation in the research on hard magnetic materials in Czechoslovakia is characterized by a rapid development and a extension in several laboratories. The research activity includes rare earth cobalt magnets, high coercive ferrites and technology. A remarkable progress in the basic research is due to the introduction of research programs coordinated by the Academy of Sciences.

Two critical raw materials in permanent magnet production are actually cobalt and samarium. Although the proven world deposits of cobalt are considered adequate in the long run, the high price and relatively tight supply of cobalt are expected to remain so for next several years. As a consequence, research into effective substitutes and increasing recycling is becoming a necessity. The current cobalt situation has accelerated the shift from Alnicos to hard ferrites and has increased the interest in the Mn—Al, low cobalt Fe—Cr—Co, powder and elongated single domain Fe magnets. The RCo_5 and $R_2(Co,M)_{17}$ magnets, while high in cobalt content are more efficient in the use of cobalt than the Alnicos because of their high energy product and coercive force. The total availability of samarium is not sufficient to meet prospective industry demands on high energy magnets, thus providing an incentive for the increased use of mischmetal cobalt magnets.

To satisfy a variety of requirements concerning the increase of magnetic induction supplied into an air gap or into other parts of the magnetic circuit, a new type of permanent magnets was developed in SVÚM. These magnets, being made from high coercive materials have a non-homogeneous anisotropic structure which concentrates the magnetic flux in the region of the pole and raises the value of magnetic induction when compared with conventional anisotropic permanent magnets.

Important applications which make new specific demands on the properties of magnets are in the coming. Among such uses there are effective magnetic bearings, levitated vehicles, high speed, high torque and low inertia motors, bubble memories, and new applications of rare earth cobalt magnets with a zero temperature coefficient in precision measuring instruments and microwave devices. High energy product permanent magnets represent a significant new level of power output per unit weight in comparison with conventional wound electromagnetic excitation.

It seems that the solution of the following problems could lead to an increased usage of new types of permanent magnets:

— Effective substitutions of cobalt.
— Replacement of samarium by cheaper rare earth metals. There is still much to be learned about the uniqueness of Sm relative to high coercivities in R—Co systems when compared with other rare earths.
— Improvement of the coercivity of the precipitation-hardened $R_2(Co,M)_{17}$ alloys.
— Cheaper manufacture of oriented Mn—Al and rare earth cobalt magnets.
— Reduction of stray flux by an improved design of magnetic circuits.

— Development of novel transition metal compounds with large magnetization.

— A better understanding of the nucleation of reverse domains and of the interaction of domain walls with various defects and surface.

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Because of the brief summary, many other sources are not quoted here.

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